Topic B – Human Biochemistry
B1-6 SL
B1-9 HL

IB Chemistry

Topic B – Biochem

B1 Energy - 0.5 hour

- B.1.1 Calculate the energy value of a food from enthalpy of combustion data. (2)

B2 Proteins - 3 hours

- B.2.1 Draw the general formula of 2-amino acids. (1)
- B.2.2 Describe the characteristic properties of 2-amino acids (2)
- B.2.3 Describe the condensation reaction of 2-amino acids to form polypeptides. (2)
- B.2.4 Describe and explain the primary, secondary ('-helix and (-pleated sheets), tertiary and quaternarystructure of proteins. (3)
- B.2.5 Explain how proteins can be analysed by chromatography and electrophoresis. (3)
- B.2.6 List the major functions of proteins in the body. (1)

B3 Carbohydrates - 3 hours

- B.3.1 Describe the structural features of monosaccharides. (2)
- B.3.2 Draw the straight-chain and ring structural formulas of glucose and fructose. (1).
- B.3.3 Describe the condensation of monosaccharides to form disaccharides and polysaccharides. (2)
- B.3.4 List the major functions of carbohydrates in the human body. (1)
- B.3.5 Compare the structural properties of starch and cellulose, and explain why humans can digest starch but not cellulose. (3)
- B.3.6 State what is meant by the term dietary fibre. (1)
- B.3.7 Describe the importance of a diet high in dietary fibre. (2)

B4 Lipids - 3.5 hours

- B.4.1 Compare the composition of the three types of lipids found in the human body. (3)
- B.4.2 Outline the difference between HDL and LDL cholesterol and outline its importance. (2)
- B.4.3 Describe the difference in structure between saturated and unsaturated fatty acids. (2)
- B.4.4 Compare the structures of the two essential fatty acids linoleic (omega–6 fatty acid) and linolenic (omega–3 fatty acid) and state their importance. (3)
- B.4.5 Define the term iodine number and calculate the number of C=C double bonds in an unsaturated fat/oil using addition reactions. (2)
- B.4.6 Describe the condensation of glycerol and three fatty acid molecules to make a triglyceride. (2)
- B.4.7 Describe the enzyme-catalysed hydrolysis of triglycerides during digestion. (2)
- B.4.8 Explain the higher energy value of fats as compared to carbohydrates. (3)
- B.4.9 Describe the important roles of lipids in the body and the negative effects that they can have on health. (2)

B5 Micronutrients and macronutrients - 2 hours

- B.5.1 Outline the difference between micronutrients and macronutrients. (2)
- B.5.2 Compare the structures of retinol (vitamin A), calciferol (vitamin D) and ascorbic acid (vitamin C). (3)
- B.5.3 Deduce whether a vitamin is water- or fat-soluble from its structure. (3)
- B.5.4 Discuss the causes and effects of nutrient deficiencies in different countries and suggest solutions. (3)

B6 Hormones - 3 hours

- B.6.1 Outline the production and function of hormones in the body. (2)
- B.6.2 Compare the structures of cholesterol and the sex hormones. (3)
- B.6.3 Describe the mode of action of oral contraceptives. (2)
- B.6.4 Outline the use and abuse of steroids. (2)

HL Material

Topics 7-9 are for HL students only

(HL) B7 Enzymes - 3 hours

- B.7.1 Describe the characteristics of biological catalysts (enzymes). (2)
- B.7.2 Compare inorganic catalysts and biological catalysts (enzymes). (3)
- B.7.3 Describe the relationship between substrate concentration and enzyme activity. (2)
- B.7.4 Determine Vmax and the value of the Michaelis constant (Km) by graphical means and explain its significance. (3)
- B.7.5 Describe the mechanism of enzyme action, including enzyme substrate complex, active site and induced fit model. (2)
- B.7.6 Compare competitive inhibition and non-competitive inhibition. (3)
- B.7.7 State and explain the effects of heavymetal ions, temperature changes and pH changes on enzyme activity. (3)

(HL) B8 Nucleic acids - 3 hours

- B.8.1 Describe the structure of nucleotides and their condensation polymers (nucleic acids or polynucleotides). (2)
- B.8.2 Distinguish between the structures of DNA and RNA. (2) RNA has ribose as its pentose sugar; DNA has deoxyribose. Deoxyribose lacks an oxygen atom on C2. RNA has uracil instead of thymine as its base. RNA is a single-strand nucleic acid; DNA is a doublestrand nucleic acid.
- B.8.3 Explain the double helical structure of DNA. (3)
- B.8.4 Describe the role of DNA as the repository of genetic information, and explain its role in protein synthesis. (2)
- B.8.5 Outline the steps involved in DNA profiling and state its use. (2)

B9 Respiration - 1 hour

- B.9.1 Compare aerobic and anaerobic respiration of glucose in terms of oxidation/reduction and energy released. (3)
- *B.9.2 Outline the role of copper ions in electron transport and iron ions in oxygen transport. (2)*

Topic B1 - Energy

- B.1.1 Calculate the energy value of a food from enthalpy of combustion data. (2)

B1.1 - Living Organisms

Introduction

- Living organisms have to be able to:
  - Exchange matter and energy with their surroundings.
  - Transform matter and energy into different forms.
  - Respond to changes in their environment.
  - Grow.
  - Reproduce.

B1.1 - Macromolecules

- All of these changes are due to large organic compounds called **macromolecules**.
  - A macromolecule is a combination of many smaller similar molecules polymerized into a chain structure.
- In living organisms there are three main types of macromolecules which control all activities and determine what an organism will do and become.
  - Proteins.
  - Carbohydrates
  - Nucleic acids.

B1.1 - Cells

- The basic unit of life is the **cell.**
  - The cell makes up all living organisms that we know of.
  - Cells are in turn made of macromolecules that form inside the cell.
  - Other macromolecules control the formation of these macromolecules.
- **Metabolism** is the breaking down or building up of macromolecules.
  - Generally, breaking down macromolecules releases energy that the organism can use as an energy source.
  - The building up of macromolecules requires energy, that is obtained from breaking down macromolecules.

B1.1 - Respiration

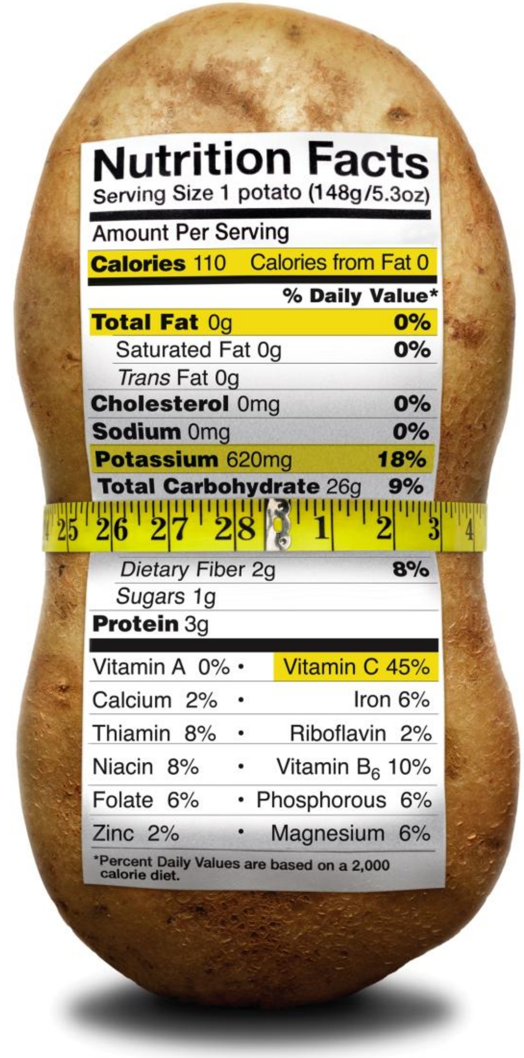
- Energy is made available in the body through a series of reactions known as **respiration**.
  - Usually begins with the simple sugar molecule glucose.
  - Other energy-rich molecules are usually first converted into glucose or intermediates by metabolic processes.
- The body is therefore dependent on a continuous supply of energy-rich molecules to drive the reactions of metabolism.
  - The source of these molecules is our diet, so knowing the energy content of different food types is of great importance.

B1.1 – Respiration 2

- It is estimated that moderately active men and women require the following energy consumption per day
  - Women = 9200 kJ
  - Men = 12600 kJ
- If we intake a greater quantity of energy-rich molecules than needed, most is converted into storage molecules such as fat for later use.
- The concept of 'dieting' effectively reverses this process by ensuring that we take in less energy-rich food than the body needs, so that these stored molecules are used up to provide the energy

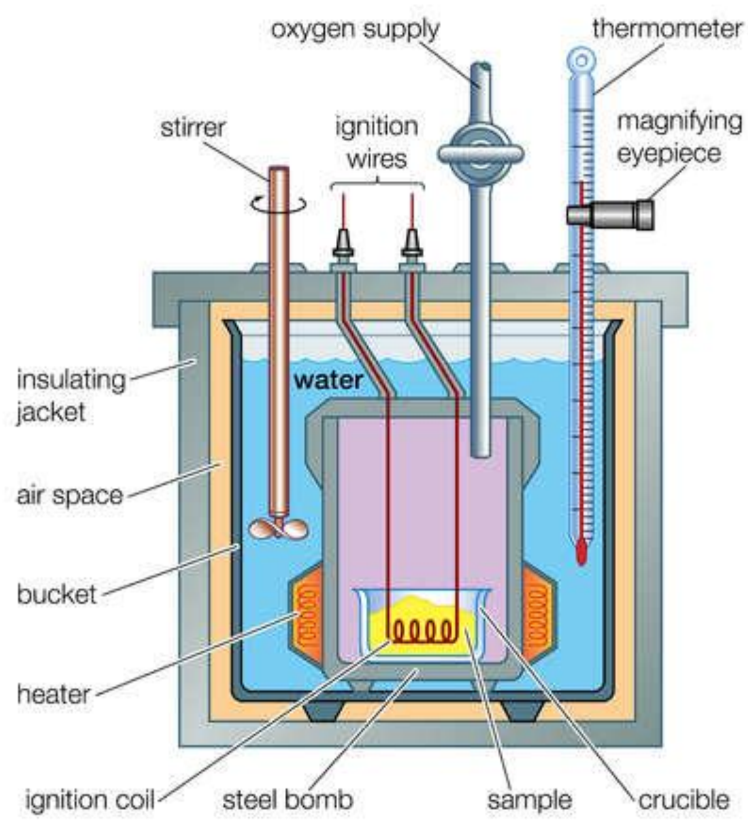
B1.1 – Food Energy

- Many foods display their energy values on packaging (in the states it's required). This food undergoes an enzyme-controlled combustion known as respiration
- Although we can't measure the energy directly, we can measure the enthalpy changes for dried samples of the food with use of a bomb calorimeter.



B1.1 - Calorimetry

- Food is burned to completion after being ignited electrically (the bomb) and the heat released as it burns is measured by recording the temperature rise in a known mass of pure water.
- We use the equation
  - $q = mc\Delta T$
  - Energy lost = energy gained
    - $q_{food} = -(q_{H2O})$



Bomb Calorimeter

B1.1 - Equations for Heat Change (q)

The ***specific heat*** (*c*) of a substance is the amount of **heat (*q*)** required to raise the temperature of **one gram** of the substance by **one degree** Celsius.

Usually use specific heat, but you can use the ***heat capacity*** (***C***) as well [c substance is the amount of **heat (*q*)** required to raise the temperature of a given quantity in **mass (*m*)** of the substance by **one degree** Celsius.]

$$C = mc$$

Table 6.1 **The Specific Heats of Some Common Substances**

Substance	Specific heat (J/g · °C)
Al	0.900
Au	0.129
C (graphite)	0.720
C (diamond)	0.502
Cu	0.385
Fe	0.444
Hg	0.139
H_2O	4.184
C_2H_5OH (ethanol)	2.46

Heat (*q*) absorbed or released:

$$q = mc\Delta t$$

$$q = C\Delta t$$

$$\Delta t = t_{final} - t_{initial}$$

B1.1 - Variables for Heat Change:

- **q**, is the **<u>heat change</u>** within the system
- **c**, is the **<u>specific heat</u>** of the substance
  - Does not take into account the mass
  - Use the equation $q = ms\,\Delta T$
- **<u>C</u>**, is the **<u>heat capacity</u>** of the substance
  - Takes into account the mass
  - Use the equation $q = C\,\Delta T$
- **m**, is the **<u>mass</u>** of the substance
- **ΔT**, is the **<u>change in temperature</u>**
  - $\Delta T = T_f - T_i$

B1.1 – Calorimetry Review

- A 0.78 g sample of a food substance was combusted in a bomb calorimeter and raised the temperature of 105.10 g of water from 15.4^oC to 30.6^oC. Calculate the energy value of the food in kJ/g.
  - m_{H2O} = 105.10 g
  - ΔT = Tf-Ti = 30.6-15.4 = 15.2^oC or 15.2 K
  - c_{H2O} = 4.184 J/g^oC
  - q = mcΔT = (105.10 g)(4.184 J/g^oC)(15.2^oC)
  - q = 6677.63 J per 0.78 g sample heated
  - Energy value = 6677.63 J / 0.78 g
    - Energy = 8561.1 J/g OR 8.56 kJ/g

B1.1 - Calorimetry

- You may be asked to express your answer in J/mol instead of J/g
  - A simple conversion with molar mass will get you there
  - Ex. 1.50 g of glucose, $C_6H_{12}O_6$, was completely combusted in a bomb calorimeter. The heat evolved raised the temperature of 225.00 g of water from 18.50^{o}C to 27.96^{o}C. Calculate the energy value of glucose in kJ/mol.

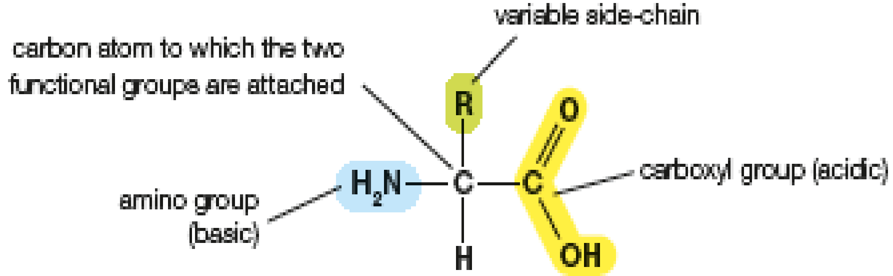
B2 Proteins - 3 hours

- B.2.1 Draw the general formula of 2-amino acids. (1)
- B.2.2 Describe the characteristic properties of 2-amino acids (2)
- B.2.3 Describe the condensation reaction of 2-amino acids to form polypeptides. (2)
- B.2.4 Describe and explain the primary, secondary ('-helix and (-pleated sheets), tertiary and quaternary structure of proteins. (3)
- B.2.5 Explain how proteins can be analyzed by chromatography and electrophoresis. (3)
- B.2.6 List the major functions of proteins in the body. (1)

B2.6 - Proteins

Proteins

- Proteins are macromolecules that are **polymers** of amino acids. They have two main roles
- **Structural Proteins**; proteins go into making muscle tissue, connective tissue, and skin, hair, and nails, just to name a few.
- **Function Proteins;** proteins are enzymes which catalyze biochemical reactions
  - Building up macromolecules requires energy and an enzyme lowers the amount of energy that is necessary.
  - Also as messengers known as hormones

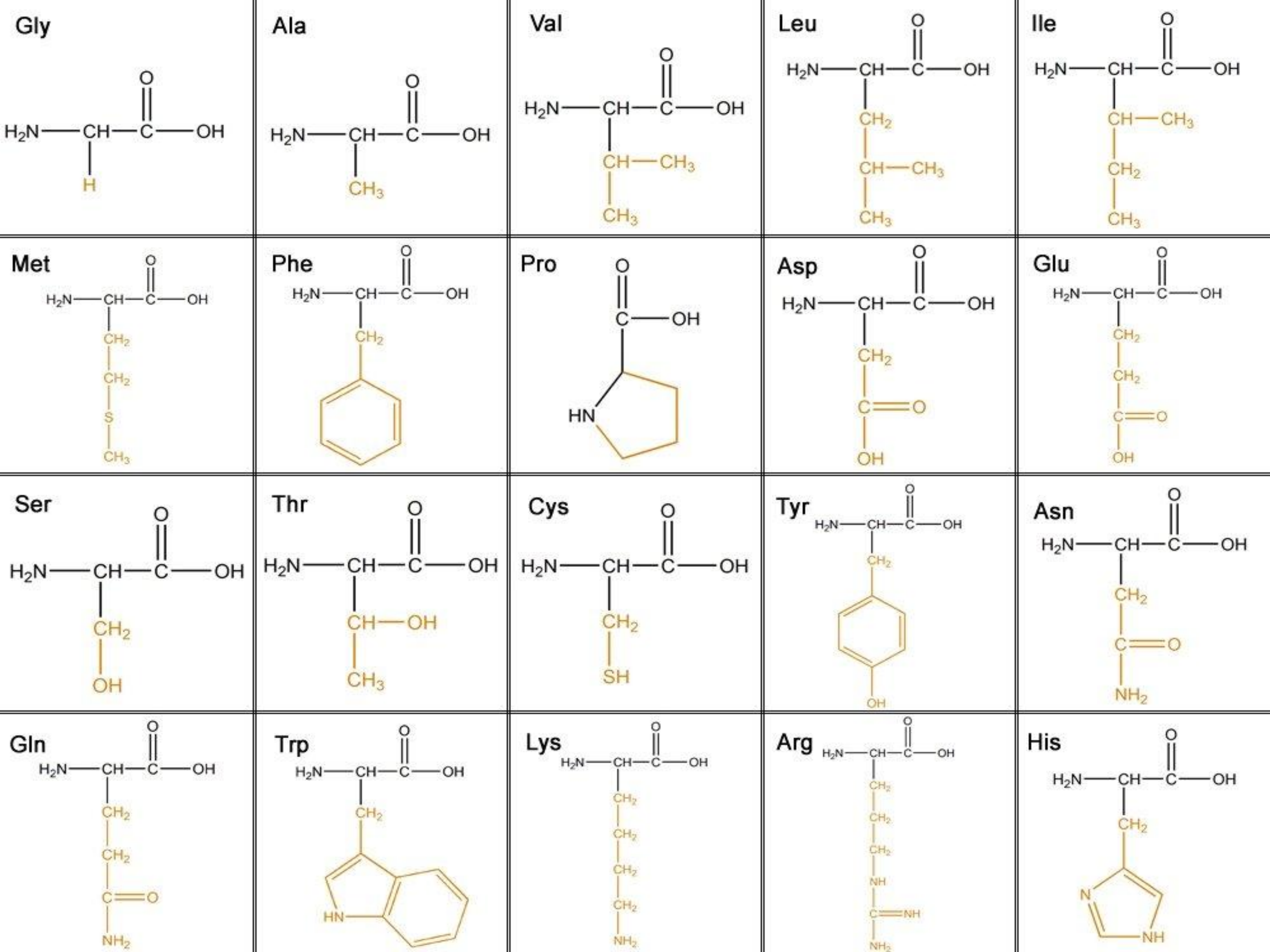


B2.6 – Proteins Function

Role of Protein	Example	Specific Function
Structural	Keratin	Protective covering in hair and fingernails
Structural	Collagen	Connective tissue in skin and tendons
Structural	Myosin	Contractile action in muscles to bring about movement
Enzyme (catalyst)	Lactase	Hydrolyses lactose into glucose and glactose
Hormone	Insulin	Controls and maintains the concentration of glucose in the blood
Protective mechanisms	immunoproteins	Act as antibodies which help destroy foreign proteins (e.g. from bacteria) in the blood
Transport molecules	Hemoglobin	Carries oxygen from the lungs to all respiring cells
Storage molecules	Casein	Food substance in milk
Lubrication	Mucoproteins	Mucous secretions to reduce friction in many parts of the body, e.g. the knee joint

B2.1 - Amino Acids and Proteins

- Amino Acids are the building blocks of proteins
- There are 20 amino acids that go into producing proteins.
  - Each have a carboxylic acid AND an amino group
    - COOH, loses an OH group and NH_2 loses an H, forming a bond between two amino acids and water.
  - These amino acids are polymerized by a dehydration synthesis to form long chains of repeating amino acids called a protein. (taking water out)
  - The arrangement of the amino acids in the polymer determine the structure of the protein which confers to it is function or structural attributes.
    - Meaning the shape/order/structure of the amino acids in a protein determines it's function


Gly
Ala
Val
Leu
Ile
Met
Phe
Pro
Asp
Glu
Ser
Thr
Cys
Tyr
Asn
Gln
Trp
Lys
Arg
His

B2.1 - Essential Amino Acids

- Of the 20 amino acids that make up proteins 10 of them can be synthesized by the human body
- The other 10 amino acids must be acquired from food sources. These amino acids are known as essential amino acids

B2.1 - Essential Amino Acids

Essential amino acids

- Arginine
- Histidine
- Isoleucine
- Leucine
- Lysine
- Methionine
- Phenylalanine
- Threonine
- Tryptophan
- Valine

Non-Essential amino acids

- Alanine (from pyruvic acid)
- Asparagine (from aspartic acid)
- Aspartic Acid (from oxaloacetic acid)
- Cysteine
- Glutamic Acid (from oxoglutaric acid)
- Glutamine (from glutamic acid)
- Glycine (from serine and threonine)
- Proline (from glutamic acid)
- Serine (from glucose)
- Tyrosine (from phenylalanine)

B2.1 - Essential Amino Acids

Complete protein

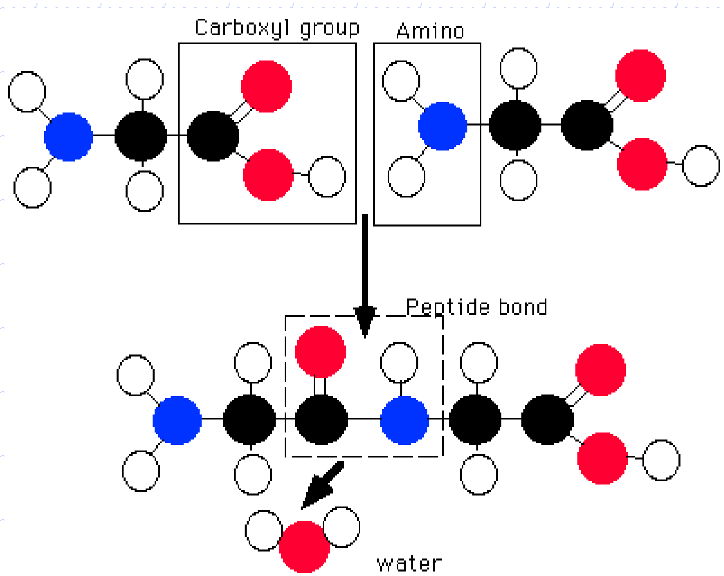
- Contains all 10 essential amino acids
- Proteins derived from animal sources are complete proteins
- Beans contain some complete protein as well

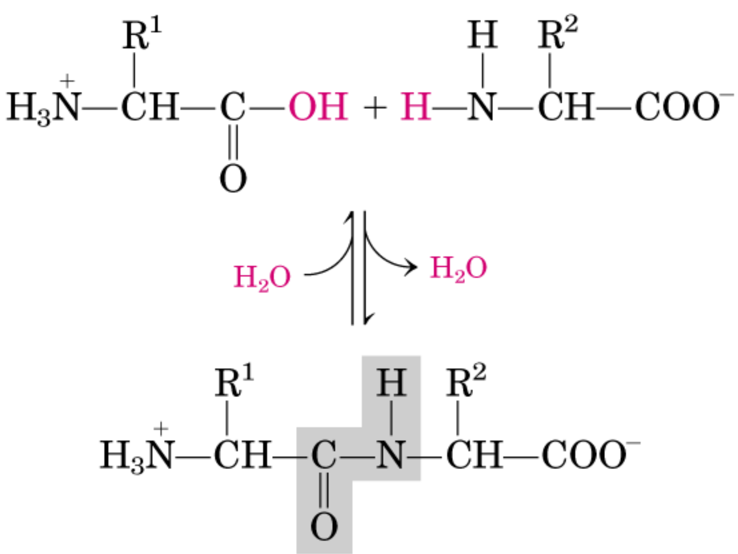
Incomplete protein

- Lack one of more of the essential amino acids
- Most vegetable proteins are incomplete proteins
- Beans are an exception to this generalizations

B2.3 – Condensation, dehydration synthesis

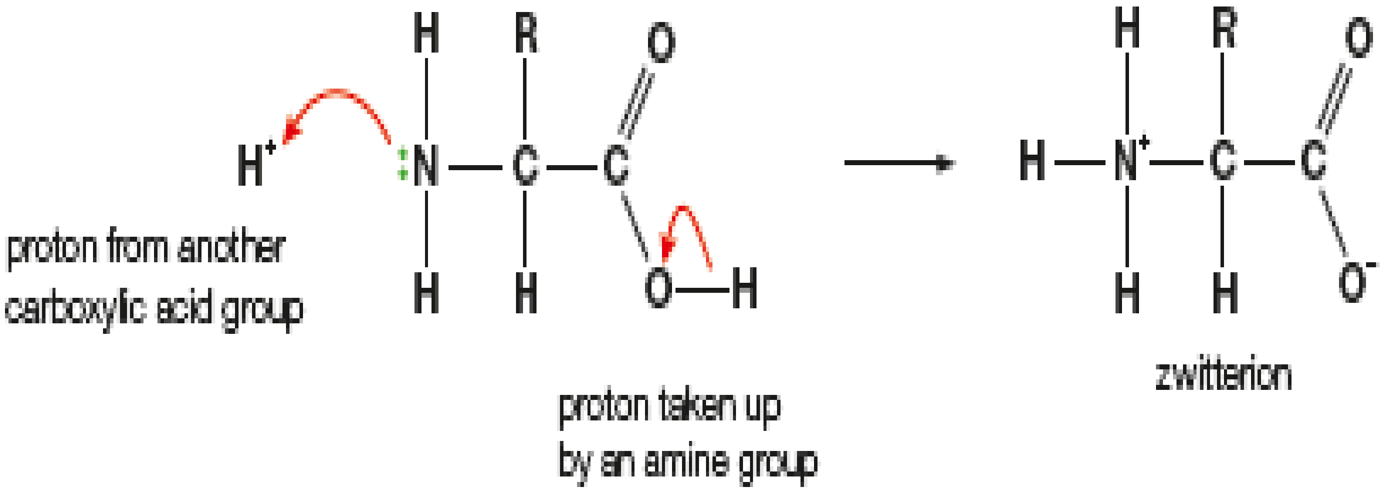
- With three-letter abbreviations.
- These twenty amino acids that make up proteins, can be linked together through dehydration synthesis.
- The carboxyl group of one amino acid bonds with the amino group of a second acid to yield a **dipeptide** and water. Proteins are long chains of amino acids linked by peptide bonds.





B2.2 - Amino Acids are Amphoteric

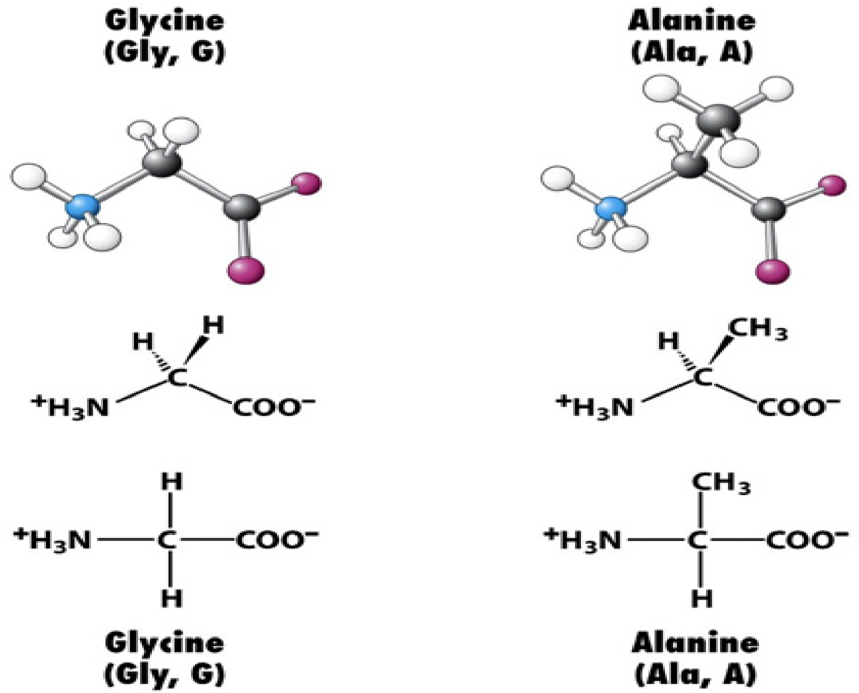
- Amino acids are **amphoteric.** They are capable of behaving as both an acid and a base, since they have both a proton donor group and a proton acceptor group.



- In neutral aqueous solutions the proton typically migrates from the carboxyl group to the amino group, leaving an ion with both a (+) and a (-) charge.

B2.2 – (1) The Zwitterion

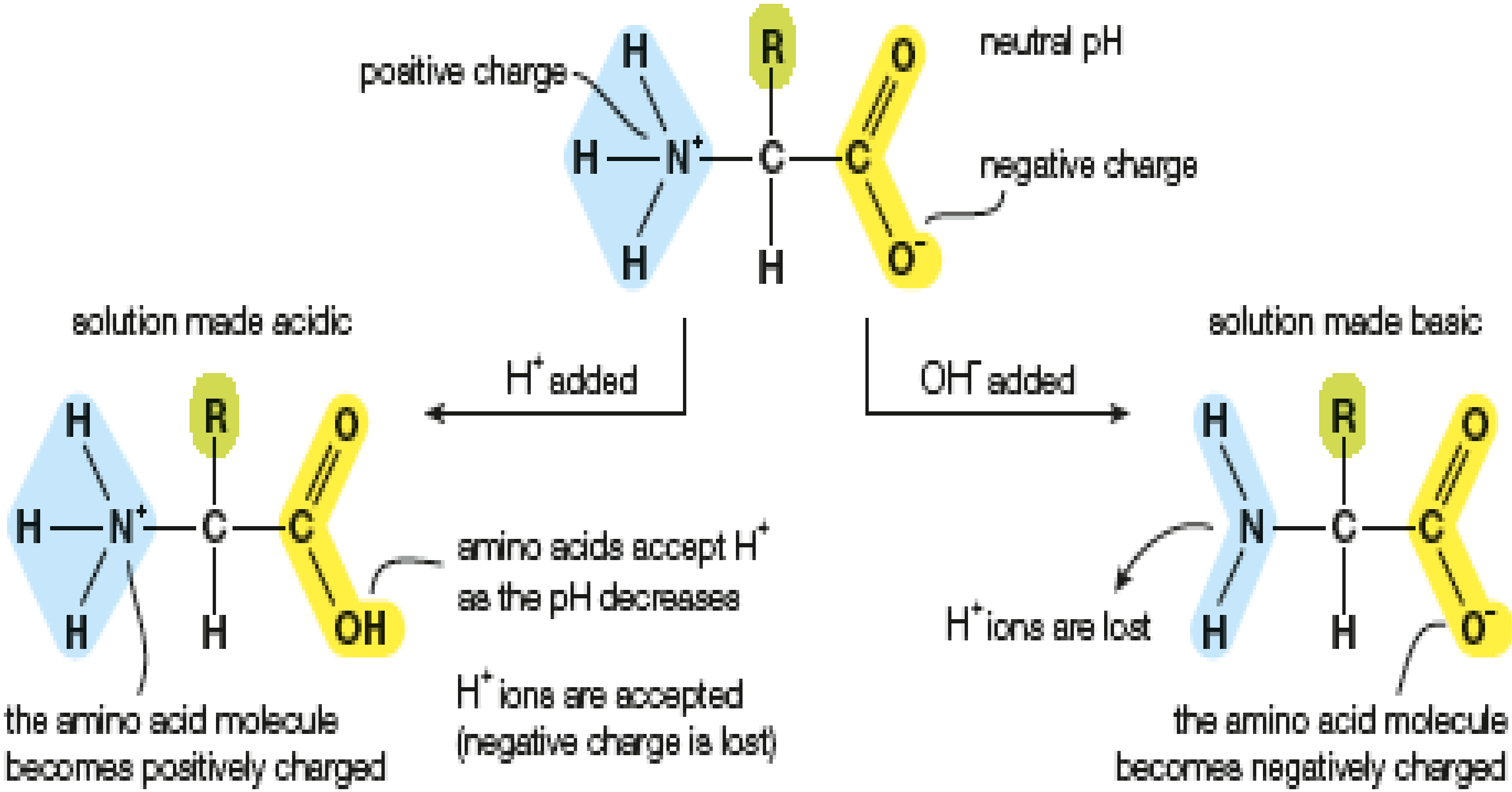
- Crystaline amino acids have relatively high melting or decomposition points.
- Soluble in polar solvents.
- Amino acids exists as dipolar ions known as **Zwitterions.**
- Internal acid-base reaction, a hydrogen ion is transferred fro the carboxylic acid to the amino group.



B2.2 – (2) Buffer Action

- In aqueous solution the amino and carboxylic acid functional groups both ionize or dissociate
- Carboxylic group releases hydrogen ions and hence acts as a Bonsted-Lowry acid
  - $-COOH\ (aq) \leftrightarrow -COO^{-}\ (aq) + H^{+}\ (aq)$
- The amino group can accept a hydrogen ion from solution and so acts as a Bronsted-Lowry base
  - $-NH_2\ (aq) + H^{+}\ (aq) \leftrightarrow -NH_3^{+}\ (aq)$
- In solutions of neutral (both dissociated), acidic (low pH, amino acid accepts hydrogen, +), basic (high pH, amino acid donates hydrogen, -)
- Consequently, amino acids regulate the pH of a system by "mopping up or donating H^{+} ions)

B2.2 – (2) Buffer Action 2

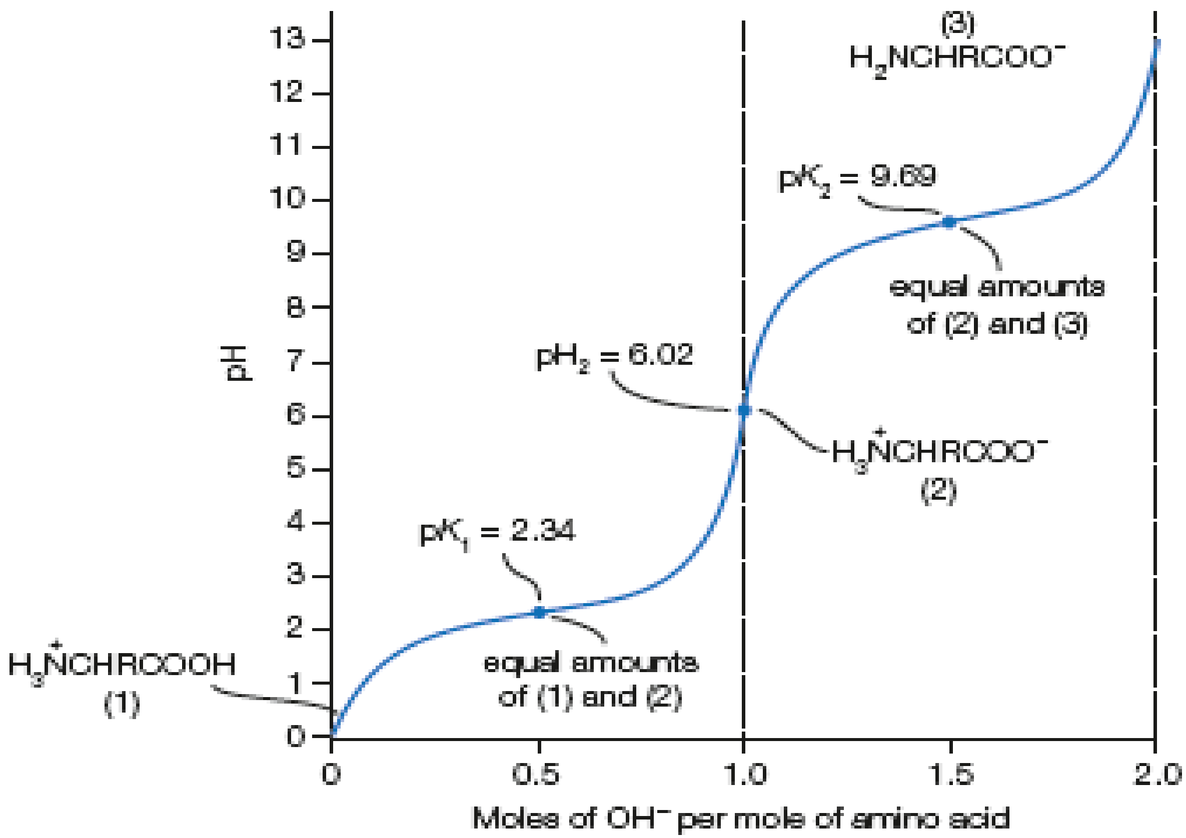


B2.2 – (3) Isoelectric Point

- Aminio acids such as alanine (where R is a methyl group) are dibasic when it's fully deprotonated. It can donate two protons H^+ when in titration with a strong base.
  - $H_3N^+CH(CH_3)COOH(aq) + OH^-(aq) \rightarrow H_3N^+CH(CH_3)COO^-(aq) + H_2O(aq)$
  - $H_3N^+CH(CH_3)COO^-(aq) + OH^-(aq) \rightarrow H_2NCH(CH_3)COO^-(aq) + H_2O(aq)$
- The isoelectric effect is the basis for a separation technique known as **electrophoresis**.

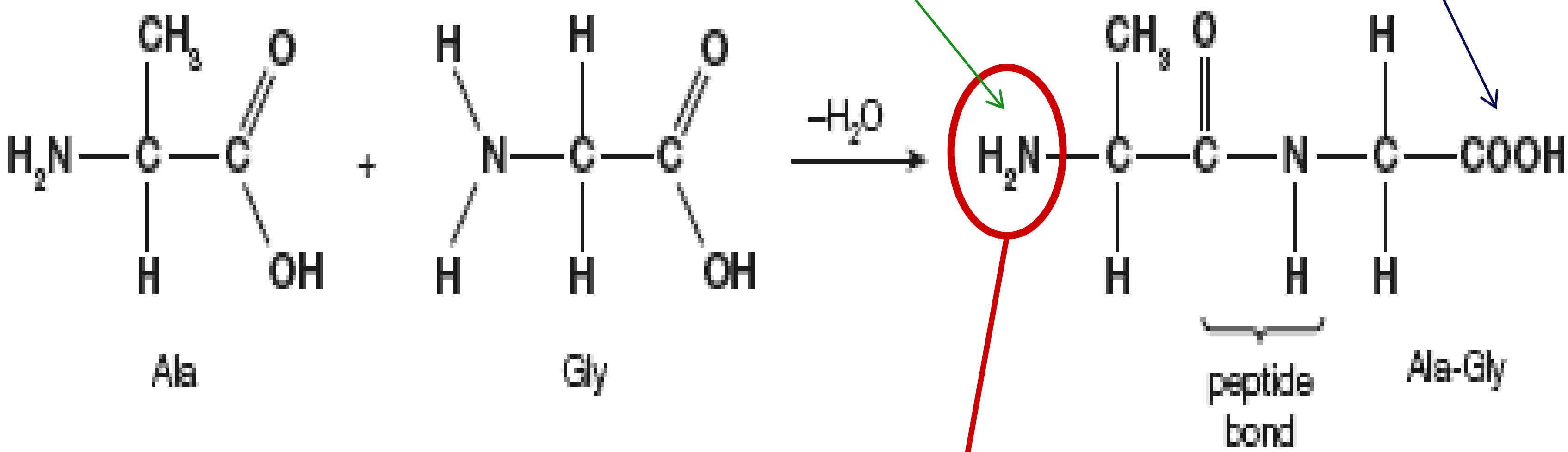
B2.2 – (3) Isoelectric Point 2

- The first part of the curve is the first reaction, the second, the second reaction. The flat parts of the curve correspond to the buffering regions where pH does not vary significantly.



B2.3 – Forming Polypeptides

- Two amino acids can combined to form a simple dipeptide



By convention, when drawing polypeptide chains the amino group is written on the left

B2.3 – Forming Polypeptides

- Chains of amino acids can form polypeptides (proteins) that are 1000’s of AA’s long
- We will get into the folding and structure of proteins in B2.4 on Friday, please read ahead.